CHAPTER 13

INDOOR AIR QUALITY

1. **GENERAL.** The indoor environment is a result of the interaction between many factors - the building's location, climate, construction methods and materials, renovations, occupant activities, furnishings - to name a few. With the focus on energy conservation in the 1970s came the idea that "tighter is better." Buildings were constructed to prevent infiltration and exfiltration, but compensation was not always made for the loss of natural ventilation. Consequently, the number of employee complaints of sickness in the workplace began to rise, and indoor air quality (IAQ) became an occupational health issue. This chapter is not an exhaustive IAQ reference. It is meant to provide general information and a list of references that should be read for a more thorough understanding of IAQ, sick building syndrome (SBS) and building related illness (BRI).

2. **DEFINITIONS.**

a. ASHRAE. American Society of Heating, Refrigerating, and Air-Conditioning Engineers.

b. Biological contaminants. Agents that are living or derived from living organisms, such as fungi, bacteria, viruses, and animal antigens. Such biologicals can be inhaled and may cause allergic reactions, hypersensitivity, and respiratory irritation. In rare instances, such agents have caused infectious diseases. Also called microbials, bioaerosols or microbiologicals.

c. Building related illness (BRI). Illnesses for which there is a clinically defined etiology and for which there may be confirming laboratory and physical evidence. Examples include legionellosis, psittacosis, and hypersensitivity pneumonitis.

d. HVAC. Heating, ventilating and air conditioning.

e. Indoor air quality (IAQ). The condition of the indoor environment, including such parameters as chemical and biological contaminants, physical hazards, and individual perceptions or reactions to these parameters. Also called indoor environmental quality (IEQ).

f. Multiple chemical sensitivity (MCS). A condition whereby an individual experiences adverse reactions or sensitivity to

multiple chemicals at extremely low concentrations. As related to IAQ, it is a controversial phenomenon without consensus about its existence, causes or resolution. Also called environmental illness.

g. Particulates. Particles, especially allergens and irritants, that can be present in the air. They can usually be eliminated through good filtration methods. Particulates may serve as a core or carrier for VOCs or other chemicals. Also called airborne particulates and total particulates.

h. Sick building syndrome (SBS). A condition associated with complaints of discomfort, that may include headache, nausea, dizziness, dermatitis, upper respiratory irritation, cough, fatigue, eye irritation, and difficulty concentrating. Specific causes for the symptoms are usually not identified, but may be a combination of chemical, physical and biological factors, and/or individual differences in sensitivity. Symptoms generally appear after spending some period of time in the work place, but lessen or disappear after leaving the work site. Also called tight building syndrome.

i. Tight building syndrome. See sick building syndrome.

j. Volatile organic compounds (VOCs). Refers collectively to the organic vapors that contaminate indoor air. More correctly, the total VOCs (TVOCs) detected during analysis include two subgroups: VOCs (boiling point less than 0 degrees centigrade (°C) to about 260°C) and semi-volatile organic compounds (SVOCs) with boiling points from about 260°C to 400°C. VOC sources include building materials, cleaners, paints, adhesives, cosmetics, solvents, and pesticides. Some VOCs typically associated with IAQ problems include benzene, xylene, toluene, methyl ethyl ketone, limonene, trichloroethylene, formaldehyde, carbon tetrachloride, and other chlorinated solvents. Also called volatiles.

3. **IAQ INVESTIGATION GUIDELINES.**

a. General.

(1) As detailed in Reference 13-1, the IAQ investigation sequence is:

(a) For buildings maintained by the Navy: (1) individuals report problems to their supervisors; (2) the supervisor coordinates with the facilities maintenance activity and activity NAVOSH manager; (3) if unable to resolve the problem locally, the NAVOSH manager requests investigation assistance from the cognizant industrial hygiene service; (4) if unable to

resolve the problem, the cognizant industrial hygiene service requests assistance from BUMED.

(b) In buildings where Navy employees work but the Navy does not maintain the building, report all problems to the facilities maintenance organization. If they are unable to resolve the problems, contact the NAVOSH manager and continue the sequence described above for buildings maintained by the Navy.

(2) IAQ evaluations require sound industrial hygiene knowledge and practice. There is no "magic formula," nor can every investigation be conducted exactly the same way. The industrial hygienist (IH) will have to plan the evaluation based on employee complaints, visual inspection and professional experience. Most evaluations will involve sick building syndrome; building related illness cases are less common.

(3) There is no clear definition for "good" indoor air quality. ASHRAE 62-1989 defines "acceptable indoor air quality" as air in which there are no harmful contaminant concentrations and with which 80% or more of the occupants are satisfied.

(4) It is usually possible to determine whether or not a problem exists in the complaint area, and to provide recommendations that will reduce or alleviate the problem. Do not dwell on identifying a specific cause for each IAQ evaluation.

(5) A three step investigation approach is recommended.

(a) Phase 1 - Initial assessment. Evaluate complaints and determine if a problem exists. Rely on observation, interviews and minimum sample collection (usually screening samples such as carbon dioxide, relative humidity and temperature). General employee complaint forms, questionnaires or interviews may be useful (see examples in Appendix 13-A).

(b) Phase 2 - Add detail. Warranted if the problem is not resolved with Phase 1, or if Phase 1 reveals that more detailed investigation is needed. Collect additional environmental samples and/or begin quantitative measurements. At this stage, you may need to consult medical or engineering professionals for assistance with further assessment.

(c) Phase 3 - Exhaustive study. This step, though rarely needed, will be required when a problem exists but cannot be resolved using standard techniques. This phase entails in-depth and detailed measurement of all potential causative agents, conducting employee interviews, distributing and evaluating questionnaires tailored for the particular investigation, and

asking employees to maintain daily logs of their symptoms (see Appendix 13-B). Questionnaires should be used sparingly, if at all, because it is difficult to interpret the questionnaire results. Employee interviews are preferred.

(6) Successful investigations often involve a team approach with other professionals (e.g., physicians, engineers).

b. Documentation review. Before visiting the complaint site, request and review any existing written documentation of the IAQ problem. This could include employee complaints or memorandums, minutes of meetings held to discuss employee concerns, previous IH samples or surveys, building ventilation drawings and pertinent medical information.

c. Interviews. Conduct interviews, as appropriate, with employers, building/facility managers, employees, occupational health staff, building maintenance personnel, facility engineers, and public works personnel.

(1) The goals of interviewing are to gain an understanding of the perceptions of the problem, to identify actual events that may have triggered or be contributing to the SBS or BRI, and to establish open communication with everyone involved.

(2) Use discretion when conducting interviews. It may be most advantageous to interview employees individually and in private. In other circumstances, employees may be more comfortable talking with you at their desks.

(3) Always be honest and non-judgmental. DO NOT show partiality to any group or individual’s side of the story. Only the facts are relevant, and the purpose is to resolve the problem to everyone’s satisfaction.

d. Sample interview questions. Appendix 13-C contains sample interview questions, meant to serve as a starting point for the investigation.

e. Walk-around inspection. Conduct a visual evaluation. Verify information obtained during the interview process and identify processes, equipment or procedures that require further investigation. Using a checklist may be helpful (see References 13-2 and 13-3).

(1) The walk-around inspection should cover the inside and outside of the complaint office or building, including the work spaces, roof, basement, attic, false ceiling spaces, equipment rooms, smoking areas, and crawl spaces.

(2) Look for potential contamination sources and problem indicators:

(a) Water damage to walls, ceilings and carpets.

(b) HVAC information - air handling unit locations, type/location of ducts, type/location of filters, state of repair, humidification equipment, condition of supply and return air grills (dirty or discolored), inappropriately located fresh air intakes or exhausts, type of heating/cooling system, inappropriately located (e.g., in a closet) or blocked thermostats, etc.

Check actual HVAC function (outside air damper setting, thermostats, overrides or resets for computer-controlled dampers or thermostats, economizer operation, etc.) against design specifications and information obtained from maintenance and engineering personnel.

(c) Chemicals (copier additives, adhesives, solvents, cleaners, pesticides, air fresheners).

(d) Location of problem building in relation to adjacent industry, landfills, exhaust/emission sources, airport, agriculture, etc.

(e) Ceiling tiles or wall panels that have been removed.

(f) Types and locations of office equipment.

(g) Types and locations of other equipment that could affect the indoor environment (e.g., portable fans or heaters, ionizers, humidifiers).

(h) Location of building exhaust vents (check for possible exhaust re-entrainment).

(i) Evidence of animals (e.g., nests or droppings).

(j) Odors, unsanitary conditions, blocked drains or vents, dry sanitary traps, etc.

f. Sample collection.

(1) In general, air samples should be taken only when there is visible evidence or when employee symptomatology is suggestive of a causative agent. For example, collecting biological samples in the absence of visual contamination is

almost always a wasted effort. Unless you are purposely documenting "zero exposure," many investigations can be resolved with little or no sampling.

(2) If specific contaminants are suspected after completing the preliminary investigation, collect air samples for the indicated contaminant(s). Otherwise, collect screening samples, and use these results to decide if long-term sampling is warranted.

(a) Screening samples should include, as a minimum, carbon dioxide, temperature, relative humidity, and air flow assessment.

(b) Commonly used sampling methods are listed in Appendix 13-D. For additional information, consult References 13-2, 13-4, 13-5, 13-6, and 13-7.

(3) Samples should be collected at outside air intakes, near return air ducts, near potential indoor and outdoor contaminant sources and in complaint and non-complaint employee work areas. At least one outdoor ambient air sample should be taken for reference. Sampling sites should be representative of complaint, control (i.e., negative) and contaminant source zones.

(4) Sampling should be done throughout the work day, such that both "worst case" and typical periods are likely to be sampled. It may be helpful to have employees keep complaint logs on sampling days to allow comparison of test results and complaints.

g. Ventilation system testing.

(1) Carbon dioxide is probably the most common measurement in IAQ evaluations. It is used as an INDICATOR of ventilation adequacy. A high incidence of employee complaints has been associated with carbon dioxide levels above 1,000 parts per million (ppm).

(2) Complete evaluation of the HVAC system should include:

(a) Air temperature, humidity, air flow, and CO_2 measurements.

(b) Inspection of the HVAC system components, including the ducts, air handling units (cooling and heating coils, condensation pans, humidifiers), filters, dampers, thermostatic controls, outside air intakes, exhausts, etc. Appendix 13-E is a sample HVAC inspection checklist. Look for

dirty/missing filters, poor intake/exhaust location, moisture problems (standing water in the condensate pan, clogged drains, water damaged ducts), dirty or deteriorating insulation (particularly if the ducts are insulated on the inside), dirty/contaminated cooling coils, closed/blocked dampers, and inoperable fans/motors.

4. **INTERPRETATION OF INDOOR AIR QUALITY SAMPLING RESULTS.**

a. Do not collect samples unless you are prepared to interpret and explain your results. This is especially true when sampling for bioaerosols or when doing scans or "panels" for chemicals. Since there are no IAQ compliance standards, be careful what comparisons you use to interpret data. Use recommendations and guidelines with the understanding that there may be other physical factors (e.g., ergonomic design, noise, vibration, lighting, video display terminal usage) or less easily defined contributors (e.g., comfort level, stress factors, job satisfaction, psychosocial influence) involved. Although such factors can profoundly influence the IAQ evaluation, they cannot be easily addressed quantitatively.

b. Appendix 13-F lists available recommendations and guidelines for IAQ chemical and biological agents. Consult the cited references for further information and clarification. Use extreme caution when interpreting results. Individual hypersensitivities can result in IAQ complaints even though sampling results are well below recommended levels.

c. Look for patterns in data, symptom onset and complaint fluctuations (especially as related to changes in, or patterns of, processes within the building). Also, comparing and contrasting results - inside versus outside, complaint versus non-complaint, morning versus afternoon, etc. - are usually more helpful than strict comparison with recommendations.

d. Natural fibers (e.g., asbestos) and man-made fibers (e.g., fibrous glass, mineral wool, refractory ceramic) may be identified as a contaminant source during IAQ investigations. These topics are adequately addressed elsewhere (see References 13-8 and 13-9).

5. **REMEDIATION.**

a. Successful IAQ remediation depends on reducing or eliminating air contaminant levels (if found) and addressing health complaints. Unfortunately, IAQ problems are often the result of a combination of factors, some of which may not be easily resolved (i.e., psychosocial influences). Remediation may also be tempered by economics - inexpensive solutions are more

likely to be accepted and implemented by building owners or employers.

b. There are "general" guidelines that may be useful, but good industrial hygiene practice is usually sufficient to alleviate IAQ problems. Never hesitate to consult with engineers (HVAC, mechanical, design), maintenance personnel or others who may have expert knowledge of building design, renovation or maintenance. Solutions are usually a multi-disciplinary effort.

c. IAQ Remediation Guidelines.

(1) Ventilation.

(a) Ensuring an adequate supply of fresh outdoor air is probably the single most effective way to resolve IAQ problems (see Reference 13-13). This may be as simple as opening outside air supply louvers or dampers.

(b) Air diffusers should be open and not obstructed to ensure adequate delivery and mixing of air. It may be necessary to relocate desks, bookcases or room dividers to enhance room air mixing.

(c) Routine HVAC preventive maintenance is a must. As a minimum, it should include checking and replacing, as necessary, dampers, belts, baffles or louvers, ducts, and filters. Make sure that ALL filters in filter banks are changed during maintenance.

(d) Relocate/redesign outside air intakes that are entraining outside contaminants. If building exhausts are potential contaminant sources, it may be necessary to raise the stacks or relocate them away from all outside air intakes.

(e) HVAC system component cleaning and antimicrobial treatment should be done following recommended guidelines and practices (see References 13-2, 13-7 and 13-10).

Use extreme caution when cleaning HVAC systems with heavy microbial contamination. Ensure that contamination is properly contained, collected and disposed and that work spaces are protected from contamination.

(2) Air treatment.

(a) Maintain temperature and humidity as recommended by Reference 13-11.

(b) If contaminants are being introduced from outside, consider additional filtration in the HVAC system. Filters may be needed for particulates, gases, or both. Electronic cleaning devices provide an alternate or additional removal system. (NOTE: If not properly installed and maintained, such electronic devices may generate ozone.)

(c) Remove and discard any damaged or damp insulation in the ventilation system. Ventilation ducts should be wrapped with foil-backed insulation rather than using ducts with internal insulation.

(3) Source Control.

(a) Immediately repair any sources of leaking water (water supply pipes, condensers, drains, roof leaks). Eliminate all standing water, especially in air handling unit drain pans.

(b) Whenever possible, discard water damaged materials or furnishings (e.g., carpet, wallboard, ceiling tiles, upholstered furniture). Thoroughly clean and disinfect remaining contaminated areas.

(c) Isolate any areas being renovated, painted or carpeted. If isolation is not feasible, consider having the work done when the building is not occupied.

(d) Adjust combustion sources (e.g., furnaces, water heaters) to ensure proper fuel burning. Ensure preventive maintenance is performed.

(e) If contributing to IAQ problems, install local exhausts as necessary to control contaminants generated by specific processes.

(f) Recommend making the building a non-smoking area. Reference 13-12 endorses this policy and provides recommendations for program implementation. As a minimum in buildings where smoking is allowed, provide a lounge with increased ventilation supply (60 cfm outdoor air per occupant, per Reference 13-13) and ensure that the room air exhausts directly outside.

(g) Remove chemical emission sources or provide non-irritating substitutes.

6. **FOLLOW-UP.**

a. ALWAYS conduct follow-up assessments. Contact by phone or site visit is recommended at least quarterly following completion of the investigation.

b. If problems persist, consider the following options:

(1) Revisit the site. Determine which recommendations have been implemented. Is there any change in employee complaints, attitudes or perceptions of employer assistance? Are there any new problems since the initial evaluation?

(2) Offer additional assistance, particularly if the building manager/employer is unsure of where or how to get started. You may be able to help prioritize recommendations, participate in planning solution strategies or provide IAQ training.

(3) Begin Phase 2 or 3 evaluation.

c. If IAQ problems cannot be resolved locally, consider requesting a Consultative Assistance Team (CAT) as outlined in Reference 13-1.

7. **REFERENCES**.

13-1 OPNAVINST 5100.23 Series, Chapter 30, Indoor Air Quality.

13-2 U.S. Environmental Protection Agency (EPA)/National Institute for Occupational Safety and Health (NIOSH). Building Air Quality: *A Guide for Building Owners and Facility Managers*. DHHS (NIOSH) Pub. No. 91-114 (EPA/400/1-91/033). Washington, DC: US Government Printing Office. 1991.

13-3 National Institute for Occupational Safety and Health. *Guidance for Indoor Air Quality Investigations*. Cincinnati, OH: NIOSH. 1987.

13-4 Occupational Safety and Health Administration (OSHA) Technical Manual, Section II, Chapter 2, Indoor Air Quality Investigation. OSHA Instruction TED 1.15. Washington, DC: U. S. Department of Labor. 1995.

13-5 OSHA. *OSHA Analytical Methods Manual*. 1990.

13-6 NIOSH. *NIOSH Manual of Analytical Methods*, 4th ed. NIOSH Pub. 94-113. Cincinnati, OH: Department of Health and Human Services. 1994.

13-7 American Conference of Governmental Industrial Hygienists (ACGIH). *Guidelines for the Assessment of Bioaerosols in the Indoor Environment.* Cincinnati, OH: ACGIH. 1989.

13-8 OPNAVINST 5100.23 Series, Chapter 17, *Asbestos*.

13-9 Navy Environmental Health Center (NEHC). *Manmade Vitreous Fibers*. NEHC Technical Manual, NEHC TM-6290.91-1 Rev A. 1997.

13-10 National Air Duct Cleaners Association (NADCA). *Mechanical Cleaning of Non-Porous Air Conveyance System Components*. NADCA 1992-01. Washington, DC: NADCA. 1992.

13-11 American National Standards Institute/American Society of Heating, Refrigerating and Air-Conditioning Engineers (ANSI/ASHRAE). *Thermal Environmental Conditions for Human Occupancy*. ANSI/ASHRAE 55-1992. Atlanta, GA: ASHRAE. 1992.

13-12 OPNAVINST 6100.2. Health Promotion Program. 25 Feb 92.

13-13 ASHRAE. *Ventilation for Acceptable Indoor Air Quality*. ASHRAE 62-1989. Atlanta, GA: ASHRAE. 1989.

8. **OTHER USEFUL REFERENCES**.

American Industrial Hygiene Association (AIHA) Technical Committee on Indoor Environmental Quality. *The Industrial Hygienist's Guide to Indoor Air Quality Investigations*. Fairfax, VA: AIHA. 1993.

AIHA. *Field Guide for the Determination of Biological Contaminants in Environmental Samples*. Fairfax, VA: AIHA. 1996.

ASHRAE. *Gravimetric and Dust-Spot Procedures for Testing Air-Cleaning Devices Used in General Ventilation for Removing Particulate Matter*. ASHRAE 52.1-1992. Atlanta, GA: ASHRAE. 1992.

ASHRAE. *Commissioning of HVAC Systems.* ASHRAE Guideline 1-1989. Atlanta, GA: ASHRAE. 1989.

Bearg, D. W.: *Indoor Air Quality and HVAC Systems.* Boca Raton: Lewis Publishers, Inc., 1993.

DHHS/NIOSH. *Indoor Air Quality Selected References*. Washington, DC: US GPO 1990-748-160/00545. 1989.

Environmental Protection Agency (EPA)/Consumer Products Safety Commission (CPSC). *The Inside Story. A Guide to Indoor Air Quality*. EPA 402-K-93-007. 1993. 36 p.

Godish, T.: *Indoor Air Pollution Control*. Boca Raton: Lewis Publishers, Inc., 1989.

Government Institutes, Inc.. *NIOSH Case Studies in Indoor Air Quality*. S. Ness, ed., Rockville: Government Institutes, Inc. 1996.

Hines, A. L., Ghosh, T. K., Loyalka, S. K., and Warder, R. C.: *Indoor Air Quality and Control*. Englewood Cliffs: PTR Prentice Hall, Inc., 1993.

Wadden, R. A. and Scheff, P. A.: *Indoor Air Pollution. Characterization, Prediction and Control.* New York: John Wiley and Sons, 1983.

World Health Organization, Report on a WHO meeting, Aug. 23-27, 1987. *Indoor Air Quality: Organic Pollutants*. EURO Reports and Studies 111.

WHO. Report on a WHO meeting, Aug. 29-Sep. 2, 1988. *Indoor Air Quality: Biological Contaminants.* WHO Regional Publications, European series No. 31.

APPENDIX 13-A

INDOOR AIR QUALITY CONCERN FORM

Name_____ Date_____

Command_____ Building _____

Room/Work Location_____ Phone _____

What is the best time to reach you?_____

This form should be used if your concern may be related to indoor air quality. Indoor air quality problems can include temperature control, ventilation, and air pollutants. Your observations are important and can help us resolve the problem as quickly as possible. Please use the space below to describe the nature of your complaint or concern, any potential causes, patterns of occurrence or other relevant information.

So that we can respond promptly, please return this form to:

_____
IAQ Manager or Contact Person

_____
Room, Building, Code, Phone

OFFICE USE ONLY

File Number_____ Received By_____ Date Received_____

APPENDIX 13-A

INDOOR AIR QUALITY QUESTIONNAIRE

Command_____ Building_____.
Room/Work Location_____ Date_____.

1. Do you have any complaints?
YES____ NO____

If YES, check any that apply:
____ temperature too cold ____ dust in the air
____ temperature too hot ____disturbing noises
____ lack of air circulation ____ odors
____ other (please specify)

2. When do these problems occur?
____ morning
____ afternoon
____ all day
____ specific time(s)
when? _____
____ specific day(s)
when?
____ no noticeable trend

3. Health problems or symptoms: Describe in three words or less each problem or adverse health effect that you experience more than two times per week.

Example: runny nose

Symptom #1 _____

Symptom #2 _____

Symptom #3 _____.

Symptom #4 _____

Symptom #5 _____

Symptom #6 _____

Do the above symptoms clear up within 1 hour after leaving work? YES____ NO____
If no, which symptom(s) persist throughout the week? (Circle appropriate symptom number)

Symptom #1 #2 #3 #4 #5 #6

Do you have any health problems or allergies that might account for any of these symptoms?
YES____ NO____.

If yes, please describe._____.
_____.

4. Check any of the following that apply to you.
____ wear contact lenses
____ operate video display terminal at least 10% of work day
____ operate photocopier at least 10% of work day
____ operate special office machines or equipment - specify type & frequency
_____.

5. Are you taking any medication? YES___ NO____.
If yes, what? _____.

6. Do you smoke? YES____ NO____.

7. Do others in your immediate work area smoke?
YES____ NO____.

8. What is your job title or position? _____.
_____.

9. Briefly describe your primary job tasks. _____.
_____.

10. Can you offer any other comments or observations about your office environment?
_____.
_____.
_____.
_____.
_____.

11. Your name (OPTIONAL)
_____.

12. Your office phone number (OPTIONAL)
_____.
_____.

OFFICE USE ONLY File number _____.

APPENDIX 13-A

OCCUPANT INTERVIEW Page 1 of 2

Command _____ Building _____ File Number _____.

Occupant Name _____ Room/Work Location _____.

Completed By _____ Title _____ Date _____.

SYMPTOM PATTERNS

What kind of symptoms or discomfort are you experiencing?

Are you aware of others who are having similar symptoms or concerns? YES ____ NO ____.

If so, what are their names and work locations?

Do you have any health conditions that may make you particularly susceptible to environmental problems?

☐ chronic cardiovascular disease ☐ chronic respiratory disease

☐ chronic neurological problems ☐ contact lenses

☐ chemotherapy or radiation therapy ☐ allergies

☐ immune system suppressed by disease or other causes

☐ other (explain)_____.

_____.

TIMING PATTERNS

When did your symptoms start?

When are they generally worst?

Do they go away? If so, when?

Have you noticed any other events (such as temperature or humidity changes, activities in the building) that tend to occur around the same time as your symptoms?

OCCUPANT INTERVIEW

File Number _____.

SPATIAL PATTERNS

Where are you when you experience symptoms or discomfort?

Where do you spend most of your time in the building?

ADDITIONAL INFORMATION

Do you have any observations about building conditions that might need attention or might help explain your symptoms (e.g., temperature, humidity, drafts, stagnant air, odors)?

Have you sought medical attention for your symptoms?

- When did you first see the doctor?

- Occupational health physician or personal physician?

Do you have any other comments?

APPENDIX 13-B

OCCUPANT DIARY

Occupant Name_____ Command_____.

Building_____ Room/Work Location_____ Phone_____.

On the form below, please record each occasion when you experience a symptom of ill health or discomfort that you think may be linked to an environmental condition in this building.

It is important that you record the time, date and your location within the building as accurately as possible. This will help us identify conditions (e.g., equipment operation) that may be associated with your problem. Also, please try to describe the severity of your symptoms (e.g., mild, severe) and their duration (the length of time that they persist). Any other observations that you think may help should be noted in the "Comments" column. Feel free to attach additional pages or use more than one line for each event if you need more room to record your observations.

Date/Time	Location	Symptom	Severity/ Duration	Comments

OFFICE USE ONLY

File Number_____ Received By_____ Date Received_____.

APPENDIX 13-C

1. **Employer/building or facility manager.**

a. What is the magnitude and distribution of employee complaints?

b. Have any employees been medically evaluated?

c. When did the complaints begin?

d. Have there been any recent changes, remodeling, renovations or repairs in the complaint area? In the building? (For example, new furniture, carpet or equipment, cleaning, painting, office procedural changes, partitions added, roof repair, etc.).

e. Do complaints increase/decrease with any pattern? That is, can you identify a seasonal pattern, morning versus afternoon, cloudy versus sunny, etc.?

f. What is the area (building) maintenance schedule for the heating, ventilating and air conditioning (HVAC) system? Who does maintenance?

g. What is the smoking policy?

h. What is the building's HVAC cycle? Is the system on a timer that shuts it off during hours of non-occupancy?

i. What is the typical employee population (number of employees, general job descriptions)?

2. **Employee.**

a. What symptoms are you experiencing? Is there a pattern?

b. Have you been examined by a doctor (nurse)?

c. When did the symptoms begin? Have you noticed any pattern?

d. Briefly describe your job.

e. What are your hobbies? (You may find that an outside interest is causing or contributing to the problem.)

f. Are you satisfied with the way your concerns are being handled?

g. Are you satisfied with your job in general?

h. Do you have specific concerns about your workplace, either in general or as related to the IAQ problem?

3. **Occupational health staff.**

a. What symptoms, if any, have you seen?

b. How many employees have you examined?

c. Do you see any symptom patterns?

4. **Building maintenance/housekeeping personnel.**

a. What is the HVAC maintenance schedule for filters, ducts, condensate pans, etc.?

b. Describe exactly what you do during the maintenance.

c. Do you add any biocides, disinfectants or scale inhibitors to the HVAC system? Boiler water? Cooling tower?

d. How often do you clean the carpets?

e. What cleaners, deodorizers, waxes, etc. are used in the building?

5. **Facility engineer/public works personnel.**

a. Ask for current building blueprints, including design specifications for the HVAC system.

b. What is the renovation history of the building? If renovations have occurred, what changes have been made to the original design?

c. When (what year) was the building built?

d. What was the original designed use of the building?

e. Has the building been used as anything other than office spaces? If so, what was its use? When did the changeover(s) occur?

f. Are any pesticides or herbicides used in/around the building? If so, ask to see the application records, including dates, chemical applied, amount and method of application, location of application, etc.

g. Have there been any renovations/repairs/changes to surrounding or adjacent buildings?

h. If there are any potential contaminant sources nearby (airports, exhaust stacks, nearby renovation projects, agriculture), what is the normal wind direction?

i. Is the ventilation system connected to the building's fire control system? If so, how is the ventilation system reset following an alarm?

j. Have there been any floods or leaks in the building?

APPENDIX 13-D

SAMPLING METHODS*

Suspected Contaminant	Possible Sampling Method
Carbon monoxide	Detector tubes, Direct reading (e.g., Ecolyzer®)
Carbon dioxide	Detector tubes Direct reading (e.g., portable gas chromatograph, infrared spectrometer)
Environmental tobacco smoke	Sample for components (CO, NO_X, aldehydes, etc.)
Formaldehyde	Sorbent tubes (e.g., coated charcoal, XAD), Impinger, Passive monitor (When using passive monitors, it may be necessary to sample longer than 8 hours.)
Nitrogen oxides	Detector tubes, Sorbent tube (TEA)
Ozone	Detector tubes
Particulates	Gravimetric (NIOSH 0500, 0600) Direct reading (e.g., light scattering, piezoelectric)
Volatile organic compounds [total VOCs or individual VOC (e.g., solvent, pesticide, etc.)]	Direct reading (e.g., photoionization) Passive monitor (TVOCs or VOC of interest) Sorbent tubes (gas chromatography/mass spectroscopy analysis) (When using passive monitors, it may be necessary to sample longer than 8 hours.)
Bioaerosols (fungi, bacteria)	Sieve impactors (e.g., Anderson sampler, 2-6 stages), Slit to agar impactor, Impingers. See Reference 13-7 for general information on sample media and collection.
Temperature	Thermometer, WBGT meter
Humidity	Psychrometer (aspirated or sling)
Radon	Electret monitor, Track-etch detector
Ventilation	Ventilation smoke tubes or candles Air flow measuring equipment (e.g., flow hood, thermoanemometer, pitot tube) Tracer gas

* "IAQ meters" are available that combine carbon dioxide, temperature and relative humidity sampling into a single unit. Depending on the manufacturer, additional sensors may be purchased for some chemicals (e.g., ammonia, sulfur dioxide, nitrogen oxides, carbon monoxide) and particulates. IAQ meters usually have datalogging capabilities that are useful for establishing contaminant patterns throughout the affected work area and/or building.

HVAC CHECKLIST - SHORT FORM Page 1 of 5

Command_____ Building_____.

Completed By_____ Date_____ File number _____.

MECHANICAL ROOM

Clean and dry?_____.

Stored refuse or chemicals?_____.

Describe items needing attention._____.
_____.

MAJOR MECHANICAL EQUIPMENT

Preventive maintenance (PM) plan in use? If yes, describe._____.
_____.
_____.

Control System

Type_____ Last calibration date_____.

System Operation_____ .
_____.

Boiler

General condition_____.

Rated BTU input_____.

Combustion air: Is there at least 1 in² free area/2,000 BTU? _____.

Fuel or combustion odors?_____.

Cooling Tower

General condition? (Clean? Leaks or overflow? Slime/algal growth?)
_____ .
_____.

Eliminator performance_____.

Biocide treatment used? If yes, list type, date of last application, visual assessment of effectiveness, etc.
_____.
_____.

Spill containment plan implemented?_____.
Dirt separator working?_____.

HVAC CHECKLIST - SHORT FORM

Command_____ Building_____ File number_____.

Chillers

Refrigerant leaks?_____.

Evidence of condensation problems?_____.

Proper storage and disposal of waste oil and refrigerant?_____.

_____.

AIR HANDLING UNIT

Unit identification_____ Area served_____.

Outdoor Air Intake, Mixing Plenum, and Dampers

Outdoor air intake location_____.

Nearby contaminant sources? If yes, describe._____.

_____.

Bird screen in place and unobstructed?_____.

Design total cfm?_____ Design outdoor air (O.A.) cfm_____.

Minimum % O.A. (damper setting)?_____.

Minimum cfm O.A. $\left(\frac{\text{total cfm x minimum \% O.A.}}{100}\right)$ = _____.

Date last tested and balanced?_____.

Results?_____.

Current O.A. damper setting (note date, time, and HVAC operating mode)_____.

_____.

Describe damper control sequence._____.

_____.

Condition of dampers and controls? (note date)_____.

_____.

Fans

Control sequence_____.

General condition (note date)_____.

HVAC CHECKLIST - SHORT FORM Page 3 of 5

Command_____ Building_____ File number_____.

Indicated temperatures: supply air_____ mixed air_____.
return air_____ outdoor air_____.

Actual temperatures: supply air_____ mixed air_____.
return air_____ outdoor air_____.

Coils

Heating fluid discharge temperature_____ Δ T_____.

Cooling fluid discharge temperature_____ Δ T_____.

Controls (describe)_____.

Condition (note date)_____.

Humidifier

Type_____.

General condition (Clean? No overflow? Slime/algal growth?) _____.

_____.

_____.

Biocide treatment used? If yes, list type, date of last application, visual assessment of effectiveness, etc.
_____.

DISTRIBUTION SYSTEM

Zone/ Room	System Type	Supply Air		Return Air		Power Exhaust		
		Ducted?	CFM	Ducted?	CFM	CFM	Control	Serves

Condition of distribution system and terminal equipment (note locations of problems)

Adequate access for maintenance?_____.

Ducts and coils clean and unobstructed?_____.

HVAC CHECKLIST - SHORT FORM Page 4 of 5

Command_____ Building_____ File number_____.

Air paths unobstructed? Supply?_____ Return?_____ Transfer?_____.

Exhaust?_____ Make-up?

Note locations of blocked air paths, diffusers, or grilles.

Any unintentional openings into plenums?

Controls operating properly?

Air volume correct?

Drain pans clean? Any visible growth or odors?

FILTERS

Location	Type/Rating	Size	Last Changed?	Condition

OCCUPIED SPACE - THERMOSTAT TYPES

Zone/ Room	Thermostat Location	What Does Thermostat Control?	Setpoints		Measured Temperature	Day/Time
			Summer	Winter		

Comments/Observations_____.

_____.

HVAC CHECKLIST - SHORT FORM Page 5 of 5

Command_____ Building_____ File number_____.

HUMIDISTAT/DEHUMIDISTAT TYPES

Zone/ Room	Humidistat/ Dehumidistat Location	What Does It Control?	Setpoints (%RH)	Measured Temperature	Day/ Time

Potential problems (note location)_____.

_____.

_____.

Thermal comfort or air circulation problems (drafts, obstructed flow, overcrowding, tampering, etc.)

_____.

_____.

Malfunctioning equipment_____.

_____.

_____.

Major sources of odors or contaminants_____.

_____.

_____.

ADDITIONAL NOTES, COMMENTS OR OBSERVATIONS

APPENDIX 13-F

INDOOR AIR CONTAMINANT GUIDELINES AND RECOMMENDATIONS (NON-INDUSTRIAL)

CHEMICAL SOURCES

1. Carbon monoxide

Reference 13F-1, Part 50.8: 9 ppm, 8 hr. average
35 ppm, 1 hr. average

Reference 13F-2: 35 ppm, TWA
200 ppm, Ceiling

Reference 13F-3, 13F-4: 30 mg/m³ (continuous exposure)

2. Carbon dioxide

Reference 13F-5: >1000 ppm indicates inadequate ventilation
(1000 ppm CO_2 is equivalent to 15 cfm fresh air per person)

<800 ppm indicates adequate fresh air
(800 ppm CO_2 is equivalent to 20 cfm fresh air per person)

300 pm is "normal" outdoor ambient

Reference 13F-6: outdoors - 250-350 ppm ambient
indoors - 1000 ppm indicates inadequate ventilation
<600 ppm indicates adequate ventilation

3. Environmental tobacco smoke (passive smoking)

Reference 13F-3: respirable particulates - 0.15 mg/m³
carbon monoxide - 5 mg/m³

4. Formaldehyde

Reference 13F-5: 0.1 ppm

Reference 13F-7: 0.75 ppm, TWA
2 ppm, STEL

Reference 13F-8: 0.2 ppm maximum emission from plywood
0.3 ppm maximum emission from particle board
(See reference for complete explanation)

Reference 13F-3, 13F-4: 0.12 mg/m³ (long and short term)

5. Nitrogen dioxide

Reference 13F-2: 1 ppm, STEL

Reference 13F-3: 0.32 mg/m³

Reference 13F-4: 0.3 mg/m³

6. Ozone

Reference 13F-1, Part 50.9: 0.12 ppm (1-hr average)
Part 50.10: 0.08 ppm (8-hr average)

Reference 13F-2: 0.1 ppm, TWA
0.3 ppm, STEL

Reference 13F-3: 0.08 mg/m³

Reference 13F-4: 0.12 mg/m³

7. Particulates

Reference 13F-1, Parts 50.6 and 50.7: 150 μg/m³, 24 hr. average PM-10 [Note: Collected as particles with aerodynamic diameter less than or equal to a nominal 10 micrometers.]
65 μg/m3, 24-hr average PM-2.5 [Note: Collected as particles with aerodynamic diameter less than or equal to a nominal 2.5 micrometers.]

Reference 13F-2: not otherwise regulated - total = 15 mg/m³, respirable = 5 mg/m³

Reference 13F-4: respirable, including ETS - 0.15 mg/m³

8. Sulfur dioxide

Reference 13F-1, Part 50.4: 365 g/m³, 24 hr. maximum

Reference 13F-3: 1.35 mg/m³ (short term)

Reference 13F-4: 0.5 mg/m³

9. Volatile organic compounds

Reference 13F-9: expect complaints when >5 mg/m³

BIOLOGICAL SOURCES

1. Thermophilic Actinomycetes

Reference 13F-10: >500/m³ associated with hypersensitivity lung illness outbreaks

2. Bacteria

Reference 13F-10: 10,000 CFU/m³ total count (average CFU/m³ of 25 C fungi plus average CFU/m³ of 35 C bacteria plus average CFU/m³ of 55 C thermophilic actinomycetes) should trigger remedial action

>500 CFU/m³ indicative of building related source, poor ventilation or overcrowding (see reference for complete explanation)

Reference 13F-11: 1,000 CFU/m³
100,000 bacteria/ml stagnant water or slime

Reference 13F-12: $>10^7$ bacteria/ml water indicates contamination

3. Fungi

Reference 13F-10: >500/m³ of any single fungus indicates building related source

Reference 13F-11: 1,000,000 fungi/gram of dust or material
100,000 fungi/ml stagnant water or slime

Reference 13F-12: $>10^5$ fungi/ml water indicates contamination

PHYSICAL SOURCES

1. Humidity

Reference 13F-13: 30-60%

2. Temperature

Reference 13F-5: Maintain habitable spaces between 30% and 60% to minimize growth of allergic or pathogenic organisms

Reference 13F-13: (see reference, Figure 2 and Table 3 for actual acceptable ranges of operative temperature and humidity)

Winter Temperature Range, F	Summer Temperature Range, F	Relative Humidity
68.5-76.0	74.0-80.0	30
68.5-75.5	73.5-79.5	40
68.0-74.5	73.0-79.0	50
68.0-74.0	72.5-78.0	60

3. Radiation (radon)

Reference 13F-3: 70 Bq/m³

Reference 13F-14: <4 pCi/L for school and residential occupancies. Above this value, conduct follow-up testing.

Average indoor level about 1.3 pCi/L.

4. Ventilation

Reference 13F-5: Office spaces - 20 cfm outdoor air/person
Smoking lounge - 60 cfm outdoor air/person

ABBREVIATIONS

Bq = becquerels
cfm = cubic feet per minute
CFU = colony forming units
hr = hour
g = microgram
L = liter
m³ = cubic meter
mg = milligram
ml = milliliters
pCi = picocuries (pico = 10^{-12}; 1 curie = 3.7×10^{10} Bq; 1 pCi/L = 37 Bq/m³))
ppm = parts per million
STEL = short term exposure limit (15 minute) TWA
TWA = 8 hour time weighted average
% = percent
C = degrees Centigrade
F = degrees Fahrenheit
> = greater than
< = less than

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